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Changes in goat milk composition during lactation and their effect on yield and quality of hard and semi-hard cheeses

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Abstract

Bulk tank goat milk from the Langston University Alpine herd was used to investigate changes in composition of goat milk during lactation and their effects on the sensory quality and yield of hard and semi-hard cheeses. Milk was analyzed for fat, protein, casein, total solids and somatic cell count (SCC) and cheese was assayed for of fat, protein and moisture. Sensory evaluation of the cheeses was performed to establish the relationship between yield, quality and sensory score. The chemical composition of goat milk changed significantly over lactation, resulting in variation in yield and sensory quality of hard and semi-hard cheeses. While casein content of goat milk did not change significantly as lactation advanced, SCC increased from early to late lactation. There were no significant differences in flavor, body and texture, and total sensory scores of either cheese type among aging times of 8, 16 and/or 24 week, which indicates that the cheeses can be consumed after 8 week for similar sensory quality as with longer aging. In hard cheese, yield was highly correlated with milk fat, protein or total solids, whereas only milk total solids content was highly correlated with semi-hard cheese yield. These findings indicate need to adjust cheese making procedures over the duration of lactation to increase milk nutrient recoveries and thus increase cheese yield. However, a year-round breeding system should minimize variation in chemical composition in bulk tank goat milk during lactation and help maintain consistent quality and yield of cheeses throughout the year.

Keywords: Goat milk; Cheese yield; Sensory quality

1. Introduction

Cheese composition, yield and sensory quality are influenced by a number of factors including animal genetics, the milk production environment and processing technologies. Production of cheese of certain composition, yield and quality from a given source

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of goat milk is of great economic concern to producers, manufacturers and consumers. Quality and composition of raw milk are among the major factors determining yield and quality of cheese. Reductions in cheese yield and quality can lead to economic losses, and a loss of 1% in cheese yield is considered intolerable to cheese makers (Lacroix et al., 1991). Studies on the influence of dairy species (i.e., cow, goat and ewe) on rennet clotting properties (RCP) of milk showed significant differences (Calvo, 1998), which could be attributable to variation in specific milk proteins as well as the structure and composition of casein micelles. There is also an association between physiological state of the animal and quality of milk used for cheese making. For instance, Brown (1995) reported that the relative amount of the breakdown products of plasmin attached to β-casein and γ-caseins resulted in an increase in the relative amount of κ-casein by approximately 50% after peak lactation compared with early lactation and 100% near the end of lactation by Saanen goats. Such compositional changes may alter processing qualities of goat milk in relation to cheese production. Studies on modeling of the lactation curves of dairy goats using the multiphasic function have provided useful information on characteristics of lactation such as initial and maximum yields, time of maximum yield and persistency (Gipson and Grossman, 1990). These characteristics were influenced by breed, parity, season of kidding and level of production (Gipson and Grossman, 1990), which consequently influences cheese yield and quality. Although quality characteristics and yield of cow milk cheese have been well established and documented, little research attention has been directed to effects of lactation stages and milk composition on yield and quality of hard and semi-hard cheeses made from goat milk. A few studies have been published on rheological properties of Cheddar-like goat cheese (Attaie et al., 1996), changes in protein profiles during aging of Caciotta, Monterey Jack and Cheddar goat cheeses (Jin and Park, 1995), and free fatty acid analysis of Cheddar-like goat cheese with different aging lengths (Attaie and Richter, 1996). Recently, Soryal et al. (2004) investigated effects of feeding systems on the composition of goat milk and yield of a soft cheese. There is clearly a need for more information on all types of goat milk cheese. This paper describes changes in composition of goat milk during lactation and their effects on the sensory quality characteristic and yield of hard and semi-hard cheeses.

2. Materials and methods

2.1. Goat milk for cheese making

Bulk tank milk less than 3 days old from the Langston University Alpine goat herd of 77–80 lactating does was used for the manufacturing of cheeses during the entire lactation from May to October, 2002. The kidding season started late in early April due to a delayed breeding and all lactating does were dried off in late October.

2.2. Cheese making

A Cheddar-like hard cheese and a washed-curd semi-hard cheese were manufactured weekly following the Cheddar and Colby cheese procedures, respectively, of Kosikowski and Mistry (1999) with slight modifications. An amount of 195 kg of bulk tank goat milk was used each batch for a total of 25 batches of each cheese during the complete lactation season. The milk was pasteurized at 63 °C for 30 min and then cooled to 32 °C in a cheese vat. One pouch of starter (MAO11, Texel Group Rhone-Poulenc, Saint-Romain, France) was added to the milk and mixed well; after 1 h, 40 ml of rennet (CHEMOSTAR Double Strength rennin, Rhodia Inc., Madison, WI, USA) was diluted with 1 l of water, added to the milk and mixed well. Both cheeses were dry-salted at 3.5% (weight/weight of curds) and scooped into 4.5 kg (10 lb) standard Wilson type molds (Kusel Equipment, Watertown, WI, USA) lined with cheese cloth. Both hard and semi-hard cheeses were initially pressed at 2.8 kg/cm^2 (40 psi) for 2 h, and then at 5 kg/cm^2 (70 psi) and 4.5 kg/cm^2 (65 psi), respectively, overnight (15 h) (A-Frame Cheese Press, Kusel Equipment, Watertown, WI, USA). The cheese blocks were taken out of the cheese press and weighed for cheese yield calculation. All cheese blocks were then air-dried on shelves in a cheese aging room (10 °C) for 2 days before being vacuum-packed (Multivac A 300/16, Multivac Inc., Kansas City, MO, USA). The vacuum-packed hard cheese was aged for 8, 16 or 24 week, and the vacuum-packed semi-hard cheese was aged for 8 or 16 week in the cheese aging room.

2.3. Chemical analysis of milk and whey samples

Two milk samples (40 ml) of each batch were collected for antibiotic residue screening and chemical analyses. All raw milk samples were checked for antibiotic residues using a SNAP Reader (IDEXX Laboratories, Inc., Westbrook, ME, USA) prior to cheese making. Fat, protein and total solids were analyzed on the cheese making day using an infrared milk analyzer (Dairylab II, Foss Electric, Denmark) calibrated monthly. A third milk sample (200 ml) was frozen at −18 °C for later analysis of casein (AOAC, 2000). Whey samples (200 g) were also kept under −18 °C for later analyses of protein content following the Kjeldahl procedure and of fat content using the Babcock method (Bradley et al., 1992). Fat and protein contents of whey samples were used for calculations of fat and protein recoveries, respectively.

2.4. Sampling and analysis of cheese samples

Cheese samples were collected on the day after production and after 8 and 16 week of aging of semi-hard cheese and after 8, 16 and 24 week of aging of hard cheese for sensory evaluation and chemical analyses. A representative cheese sample (100 g) from four corners and the center of a cheese block was taken using a cheese trier and frozen at −18 °C for later compositional and biochemical analyses. Fat content of cheese was determined by the gravimetric method using a supercritical fluid extraction (Isco, Inc., Lincoln, NE, USA). Protein content was determined by the Industrial Method N334-74 WB (Technicon Autoanalyzer II, Bran+Lubbe, Buffalo Grove, IL, USA). Total solids content of cheese was determined by freeze-drying (FTS systems, Stone Ridge, NY, USA).

2.5. Sensory evaluation

Sensory evaluation of hard cheeses was performed after 8, 16 and 24 week of aging and semi-hard cheeses after 8 and 16 week of aging. Cheese samples were evaluated for organoleptic quality by a panel of three trained and experienced judges. A maximum sensory score of 15 points were given to a perfect cheese, with 10 points for flavor and five points for body and texture (Bodyfelt et al., 1988). Quality attributes such as flavor, body and texture were assessed to establish the relationship between yield, quality and sensory score.

2.6. Cheese yield calculation

Actual cheese yield was expressed as kg/100 kg of goat milk used. Moisture-adjusted cheese yield was calculated by mathematically adjusting the actual yield using the mean moisture content of each cheese manufactured in this study.

2.7. Statistical analysis

Data were statistically analyzed using GLM procedure of SAS (SAS, 1990). Four to five batches of each cheese were made in each month and the average of each variable was used for mean comparison between months of lactation. If there were significant effects of lactation (month), mean comparisons were performed using least significant differences (LSD). Pearson correlation coefficients among variables were determined with PROC CORR of SAS. SCC values were converted into log SCC for statistical analysis.

3. Results and discussion

3.1. Goat milk composition, cheese composition and sensory characteristics

All goat milk was tested for antibiotic residue prior to cheese making. Only one batch was tested positive and thus excluded from cheese making. The overall means of composition and SCC in goat milk, and composition, sensory scores and yield of hard and semi-hard cheeses are presented in Table 1. Fat, protein and total solids content were typical compared with other reports for this while consuming normal dairy goat diets (Zeng et al., 1997; Soryal et al., 2004). However, these values were considerably lower than the average of individual Alpine goat milk reported by the American Dairy Goat Association (ADGA, 2003). Moisture contents were 38.4 and 45.7% for hard and semi-hard cheeses, respectively. Due to variations of moisture among batches within cheese types (with standard

Table 1
Overall means and standard deviations (S.D.) of chemical composition, somatic cell count (SCC) of goat milk for cheese making, and chemical composition, yield and sensory quality of hard and semi-hard cheeses

Variable	Hard cheese			Semi-hard cheese		
	N	Mean	S.D.	*N*	Mean	S.D.
Milk fat (%)	25	2.78	0.20	25	2.75	0.31
Milk protein (%)	25	2.89	0.14	25	2.92	0.18
Total solids (%)	24	10.20	0.47	25	10.24	0.64
Log SCC	25	6.28	0.13	23	6.25	0.13
Milk casein (%)	25	2.27	0.14	24	2.31	0.34
Casein:protein ratio	25	0.78	0.02	25	0.78	0.06
Cheese fat (%)	25	27.77	1.81	24	24.59	2.40
Cheese protein (%)	22	22.37	1.61	25	18.05	2.63
Cheese moisture (%)	25	38.35	2.37	25	45.69	3.95
Adjusted cheese yield (kg/100 kg of milk)	24	8.31	0.53	23	9.15	0.73
Flavor score (8 week)	25	8.77	0.60	25	8.89	0.39
Body and texture score (8 week)	25	4.38	0.53	25	4.48	0.51
Total sensory score (8 week)	25	13.15	1.04	25	13.38	0.80
Flavor score (16 week)	24	8.78	0.47	25	8.74	0.51
Body and texture score (16 week)	24	4.34	0.29	25	4.22	0.59
Total sensory score (16 week)	24	13.13	0.68	25	12.96	0.92
Flavor score (24 week)	25	8.71	0.47			
Body and texture score (24 week)	25	4.34	0.36			
Total sensory score (24 week)	25	13.05	0.74			

deviation of 2.37 and 3.95, respectively, for hard and semi-hard cheeses), the average moisture of 25 batches was used arithmetically for yield adjustment of each cheese. The moisture-adjusted yield for hard cheese was 8.3 kg/100 kg of milk while the semi-hard cheese had a higher yield of 9.2 as expected because of its higher moisture content.

Overall, both cheeses had characteristic flavor and texture. Log SCC of goat milk for cheese making was consistently high, averaging 6.28. Both casein content and the casein to total protein ratio were normal for Alpine goat milk. There were no significant differences between cheese ages in flavor score, body and texture, or total sensory score of either cheese. When comparing the sensory scores among cheese ages, it was apparent that the flavor development and body and texture of both cheeses reached the stage where the cheeses were ready for consumption at 8 week of age. During sensory evaluation, main flavor defects of some cheeses were found to be “acid” and “bitter” at early stages of ripening and “rancid” and “goaty” in the late stage. While “pasty” was identified as a major body and texture defect in some batches (particularly semi-hard cheese), “crumbly” was criticized in other batches (more often in hard cheese than in semi-hard cheese).

3.2. *Changes in composition of bulk tank milk over lactation*

Changes in gross composition and SCC of bulk tank Alpine goats’ milk for both hard and semi-hard cheeses over 6 months of lactation are shown in Table 2. In general, fat and protein contents of milk for both cheeses were higher at early and late stages of lactation than in mid-lactation ($P < 0.05$). The changes of total solids content in cheese milk followed similar patterns of fat and protein contents. The above observations are in agreement with a normal lactation of dairy goats, i.e., the solids content is high in early lactation when milk volume is low; while milk volume increases, the solids content decreases; as lactating does enter into the late lactation, milk volume decreases and milk solids increase again. However, it is important to point out that casein content of milk did not change with advancing stage of lactation as much as did the protein content along lactation. This observation could be attributed to the action of indigenous enzymes such as plasmin

Table 2
Gross composition (%) and somatic cell count (log SCC) of goat milk used for hard and semi-hard cheese making during 6 months of lactation

	Months in lactation					
	May	June	July	August	September	October
Fat (%)						
Hard cheese	$2.96^{a,b}$	2.65^{c}	2.64^{c}	2.59^{c}	$2.78^{b,c}$	3.03^{a}
Semi-hard cheese	2.80^{b}	2.74^{b}	2.63^{b}	2.52^{b}	2.59^{b}	3.28^{a}
Casein (%)						
Hard cheese	2.24^{a}	2.24^{a}	2.22^{a}	2.29^{a}	2.27^{a}	2.37^{a}
Semi-hard cheese	2.42^{a}	$2.28^{a,b}$	$2.24^{a,b}$	$2.26^{a,b}$	1.92^{b}	2.40^{a}
Proteins (%)						
Hard cheese	$2.82^{b,c}$	2.73^{c}	$2.82^{b,c}$	$2.88^{b,c}$	2.91^{b}	3.16^{a}
Semi-hard cheese	3.28^{a}	2.89^{b}	2.88^{b}	2.87^{b}	2.80^{b}	3.00^{a}
Total solids (%)						
Hard cheese	10.7^{a}	9.98^{b}	9.78^{b}	9.83^{b}	$10.26^{a,b}$	10.67^{a}
Semi-hard cheese	$10.83^{a,b}$	$10.26^{a,b,c}$	$9.93^{b,c}$	9.72^{c}	9.74^{c}	11.02^{a}
SCC (log)						
Hard cheese	6.15^{c}	$6.25^{b,c}$	$6.22^{b,c}$	$6.3^{a,b\ c}$	$6.38^{a,b}$	6.43^{a}
Semi-hard cheese	6.14^{c}	$6.18^{b,c}$	$6.19^{b,c}$	$6.22^{b,c}$	6.29^{b}	6.47^{a}

^{a,b,c}Means within a row not followed by the same superscript differ ($P < 0.05$).

present in goat milk. The casein content was nearly constant throughout lactation except for milk of semi-hard cheese during September. Somatic cell counts increased significantly as lactation advanced, which is considered normal in seasonal dairy goat herds. Lactating goats approaching drying-off and their udder health conditions could contribute to the extremely high SCC at the last stage (October) of lactation.

3.3. Composition and sensory quality of hard and semi-hard cheeses

The mean composition and sensory quality attributes at 8 week of hard and semi-hard cheeses manufactured during this study are presented in Tables 3 and 4, respectively. The fat content of hard cheese differed among months of lactation, with the highest value in May and the lowest in September ($P < 0.05$). Protein content was high in mid-lactation (June, July and August) and low in the early (May) and late (September and October) stages of lactation ($P < 0.05$). It appeared that variation in both fat and protein contents of cheeses during lactation did not correspond to the changes of fat and protein contents in goat milk. The moisture of hard cheeses was higher in mid-lactation than early and late lactation ($P < 0.05$). Cheese flavor score over lactations did not differ among months ($P > 0.05$) although the scores were numerically higher in the first two than later months. The body and texture scores and consequently the total sensory scores of hard cheese were the lowest among months in July ($P < 0.05$) when the cheese was often criticized for pasty body.

The changes of composition in semi-hard cheeses with advancing stages of lactation did not closely resemble those in hard cheeses. The fat content of semi-hard cheese was consistent until last month of lactation when it increased significantly ($P < 0.05$). Protein content however varied considerably among months of lactation ($P < 0.05$). Moisture content in the last month was higher than in the first 3 months of lactation ($P < 0.05$). Sensory scores were generally higher in early stages of lactation than in October ($P < 0.05$).

3.4. Cheese yield and efficiency of nutrient recovery over lactation

Actual cheese yield and moisture-adjusted yield of both hard and semi-hard cheeses are shown in Table 5, including fat and protein recovery data. Obviously, the semi-hard cheese had a higher yield than the hard cheese mainly due to a higher moisture content in semi-hard cheese.

Table 3
Composition (%) and sensory scores of goat milk hard cheese over 6 months of lactation

	Months in lactation					
	May	June	July	August	September	October
Fat (%)	29.45^{a}	27.75^{a,b}	28.34^{a,b}	27.55^{a,b}	26.42^{b}	27.17^{a,b}
Protein (%)	21.60^{b,c}	22.56^{a,b}	23.78^{a}	23.75^{a}	19.72^{d}	18.38^{d}
Moisture (%)	38.62^{a}	38.68^{a}	36.30^{a}	36.96^{a}	39.74^{a}	39.38^{a}
Flavor score at 8 week	9.18^{a}	9.11^{a}	8.32^{a}	8.66^{a}	8.7^{a}	8.61^{a}
Body and texture score at 8 week	4.9^{a}	4.83^{a}	3.84^{b}	4.21^{a,b}	4.25^{a,b}	4.28^{a,b}
Total sensory score at 8 week	14.8^{a}	13.95^{a}	11.17^{b}	12.87^{a,b}	12.95^{a,b}	12.89^{a,b}

^{a,b,c,d}Means within a row not followed by the same superscript differ ($P < 0.05$).

Table 4
Composition (%) and sensory scores of goat milk semi-hard cheese over 6 months of lactation

	Months in lactation					
	May	June	July	August	September	October
Fat (%)	20.78^{b}	20.34^{b}	19.83^{b}	20.37^{b}	20.30^{b}	23.45^{a}
Protein (%)	16.05^{c}	17.99^{b}	15.19^{c}	18.07^{b}	22.17^{a}	18.93^{b}
Moisture (%)	43.97^{b}	43.70^{b}	43.51^{b}	47.90^{a,b}	45.43^{a,b}	50.16^{a}
Flavor score at 8 week	9.06^{a,b}	8.98^{a,b}	9.15^{a}	8.79^{a,b}	8.77^{a,b}	8.54^{b}
Body and texture score at 8 week	4.71^{a}	4.88^{a}	4.62^{a}	4.54^{a}	4.53^{a}	3.58^{b}
Total Sensory score at 8 week	13.77^{a}	13.86^{a}	13.77^{a}	13.33^{a}	13.30^{a}	12.12^{b}

^{a,b}Means within a row not followed by the same superscript differ ($P < 0.05$).

Because of variation in moisture content among individual batches, actual yields of both hard and semi-hard cheeses were adjusted using the average of 25 batches made in the study respectively for yield comparison. In cow milk cheeses, the adjustment is usually done using an established moisture standard for a particular cheese variety, such as 38% for Cheddar. In goat milk cheese, however, such information is unavailable.

In hard cheese, the actual yield was higher at early (May) and late (September and October) stages of lactation compared to the mid-lactation (July and August) ($P < 0.05$) and the observation was even more obvious in moisture-adjusted yield. These findings corresponded to the changes in fat, protein and total solids content of goat milk. On the contrary, in semi-hard cheese, only milk from last month of lactation resulted

Table 5
Cheese yield (kg/100 kg of milk) and nutrient recovery (%) of goat milk hard and semi-hard cheeses over 6 months of lactation

	Months in lactation					
	May	June	July	August	September	October
Hard cheese						
Actual yield	8.75^{a,b}	8.1^{b,c}	7.38^{c}	7.73^{c}	8.5^{a,b}	9.21^{a}
Moisture-adjusted yield	8.7^{a,b}	8.03^{c}	7.79^{c}	8.04^{c}	8.22^{b,c}	8.99^{a}
Protein recovery (%)	86.13^{a,b}	81.17^{b}	85.12^{a,b}	84.76^{a,b}	87.61^{a}	83.24^{a,b}
Fat recovery (%)	87.14^{a}	80.84^{a,b}	72.37^{c}	75.22^{b,c}	81.88^{a,b}	79.76^{b}
Semi-hard cheese						
Actual yield	9.32^{a,b}	8.92^{a,b}	8.87^{a,b}	8.77^{a,b}	8.58^{b}	10.42^{a}
Moisture-adjusted yield	9.78^{a}	9.33^{a}	9.34^{a}	8.37^{a}	8.61^{a}	9.48^{a}
Protein recovery (%)	89.21^{a}	81.04^{b}	80.15^{b}	80.70^{b}	77.91^{b}	78.04^{b}
Fat recovery (%)	84.91^{a}	82.33^{a,b}	79.97^{b,c}	78.92^{b,c}	76.99^{c}	73.80^{c}

^{a,b,c}Means within a row not followed by the same superscript differ ($P < 0.05$).

in a higher actual cheese yield than milk from any other stages ($P < 0.05$). There were no significant differences in cheese yield among months of lactation ($P > 0.05$) when the actual cheese yield was moisture-adjusted.

Losses of milk fat and protein in cheese whey affect cheese yields markedly. Nutrient recovery (%) is a measure of nutrient in milk retained in cheese. It is calculated as (amount of nutrient in milk − amount of nutrient in whey)/amount of nutrient in milk × 100%. Recoveries of fat and protein were similar in hard and semi-hard cheeses, averaging 80% for fat and 84% for protein. The fat recovery of goat milk cheeses in this study was lower than those of industrial scale cow's milk cheeses (ranging from 85 to 91%) (Phelan, 1981). This observation might be resulted from smaller fat globules in goat milk. Protein recovery of goat milk cheeses was higher than those reported for cow milk cheeses (74–77%) (Callanan, 1991). Factors responsible are unclear.

Both protein and fat recoveries in hard cheese varied during lactation ($P < 0.05$), without a particular discernible pattern. In semi-hard cheese, however, both fat and protein recoveries were high at early stages of lactation and decreased as lactation advanced ($P < 0.05$). It appeared that cheese yields did not correspond to the changes of nutrient recoveries. There are many factors affecting nutrient recoveries. In Cheddar-type cheese whey (Johansen et al., 2002) reported that whey composition was found to differ between season and type of cheese in production, with the seasonal variation in protein and fat composition of the milk. Johnson et al. (2001) examined the effect of rennet coagulation time on yield and quality of Cheddar cheese and reported a decrease in the percentage of fat recovered in the cheese with increasing curd firmness. Increased firmness of coagulum at cutting increases whey removal after milling. Higher moisture content and lower pH of the cheese made from firmer curd at cutting contributes to softer, smoother-bodied cheeses without affecting the Cheddar flavor intensity.

3.5. Correlations of cheese yield and sensory scores with milk composition

Correlation coefficients of all milk variables and cheese yield and sensory scores are tabulated in Table 6 (hard cheese) and Table 7 (semi-hard cheese). In hard cheese, high correlation coefficients were found between cheese yield and milk fat, protein and total solids and ($P < 0.001$), which is in agreement with the report of Soryal et al. (2004) for goat milk Domiati cheese. However, neither milk casein content nor SCC was correlated with cheese yield ($P > 0.05$). In addition, there were no correlations between milk variables and total sensory score of cheese at any ages ($P > 0.05$) except between total solids content and sensory score at 8 week and between milk fat content and total sensory score of cheese at 24 week.

In semi-hard cheese, only total solids content of milk was highly correlated with cheese yield ($P < 0.01$), while unlike hard cheese both milk fat and protein did not correlate well with cheese yield ($P < 0.05$). Negative correlations between sensory score of cheese at 8 week and milk fat or protein were detected ($P < 0.05$). However, total solids content had no effect on total flavor scores of cheese.

In both cheeses, casein content of goat milk showed no relationships with yield ($P < 0.05$), which is in contrary to cow milk cheese (Phelan, 1981; Lacroix et al., 1991). Casein is conventionally considered as the "cheese protein" and should have a big impact on cheese yield. However, because casein content of goat

Table 6
Pearson correlation coefficients between milk chemical components (%), yield (kg/100 kg of milk) and organoleptic scores of hard cheese ($N = 25$)

	Milk fat	Milk protein	Total solids	Milk casein	Log SCC	Moisture-adjusted cheese yield	Total sensory score (8 week)
Moisture-adjusted cheese yield	0.79^{***}	0.74^{***}	0.75^{***}	0.37^{NS}	0.21^{NS}		
Total sensory score at 8 week	0.35^{NS}	0.14^{NS}	0.44^{*}	-0.11^{NS}	-0.16^{NS}	0.22^{NS}	
Total sensory score at 16 week	0.29^{NS}	0.09^{NS}	0.26^{NS}	-0.35^{NS}	-0.13^{NS}	0.14^{NS}	0.65^{***}
Total sensory score at 24 week	0.48^{*}	0.17^{NS}	0.37^{NS}	0.09^{NS}	-0.29^{NS}	0.24^{NS}	0.62^{***}

NS: not significantly different ($P > 0.05$)l.
* $P < 0.05$.
*** $P < 0.001$.

Table 7
Pearson correlation coefficients between milk chemical components (%), yield (kg/100 kg of milk) and organoleptic scores of semi-hard cheese ($N = 25$)

	Milk fat (%)	Milk protein (%)	Total solids (%)	Milk casein (%)	Log SCC	Moisture-adjusted cheese yield	Total sensory score (8 week)
Moisture-adjusted cheese yield	0.34^{NS}	0.38^{NS}	0.54^{**}	0.43^{NS}	0.32^{NS}		
Total sensory score at 8 week	-0.45^{*}	-0.45^{*}	-0.18^{NS}	-0.16^{NS}	-0.63^{***}	-0.06^{NS}	
Total sensory score at 16 week	-0.41^{*}	-0.38^{NS}	-0.16^{NS}	-0.04^{NS}	-0.50^{***}	0.05^{NS}	0.68^{***}

NS: not significantly different ($P > 0.05$).
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

milk for cheese making in this study was almost constant throughout lactation, it was speculated that any correlation if existed between cheese yield and casein content would be impossible to detect statistically.

SCC (log) in goat milk was not significantly related to cheese yield ($P > 0.05$). While there were no significant correlations between SCC (log) of milk and total sensory scores of hard cheese ($P > 0.05$) (Table 6), highly negative relationships between SCC (log) of milk and total sensory scores of semi-hard cheese at 8 and 16 week of age ($P < 0.001$) were observed (Table 7). A highly positive correlation of total sensory scores between cheese ages was detected in both cheeses. Statistical analysis did not show changes in flavor score, body and texture score or total sensory score between cheese ages ($P > 0.05$). These observations indicate that both hard and semi-hard cheeses developed well after 8 week of aging and should be ready for consumption. Continuous aging afterwards did not enhance flavor or body and texture.

4. Conclusion

Results from the current study showed that chemical composition of goat milk changed significantly over lactation, resulting in variation in yields and sensory qualities of hard and semi-hard cheeses. While casein content of goat milk did not change significantly as lactation advanced, SCC increased from early lactation to late lactation. This study also showed there were no significant differences in flavor, body and texture, and total sensory scores of both cheeses between 8, 16 and/or 24 week aging, which indicate that the cheeses should be marketed and consumed after 8 week of aging. In hard cheese, high correlation coefficients were found between milk fat, protein or total solids and cheese yield. The findings from this study revealed the need to adjust cheese making procedures over the duration of lactation to increase milk nutrient recoveries and thus increase cheese yield. A larger number of observations and a smaller size of batches are recommended for future studies on cheese yield. Flavor compounds should be further determined and texture profile analysis applied to monitor the delicate changes of flavor and texture in goat milk cheeses during aging process to complement sensory evaluation.

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